Available online at www.sciencedirect.com
SCIENCE DIRECT®
Surface Science 585 (2005) 135–136
SURFACE SCIENCE
www.elsevier.com/locate/susc

Surface Science Perspectives

Order in one dimension

L.W. Bruch

Department of Physics, University of Wisconsin–Madison, Madison, WI 53706, USA

Available online 25 May 2005

Keywords: Phase transitions; One dimensional chains; Silicon reconstruction; Adsorbates on nanotubes

Surface science now treats structures with approximately one-dimensional (1D) character, an even more constrained geometry than the nearly two-dimensional (2D) character of an interface or monolayer. Ordering in one dimension is yet more sensitive to thermal effects, but if the effective forces among the adsorbed species have long enough range the strongly correlated state survives at finite temperature. In a paper in this issue, Erwin and Hellberg propose [1] that this is the case for the adatoms in the barium-induced Si(111) 3×2 reconstruction. They evaluate the interactions in the adsorbed barium with an electronic structure theory and then use the parameters for the Coulomb gas of barium ions to predict a finite temperature order/disorder transition. Such an ambitious program is only occasionally fulfilled in other physics problems [2]. Indeed, they make a prediction that can be tested experimentally. Some steps in their analysis probably will draw further discussion. The adsorbed barium consists of a 2D array of chains, but they find that the character of the ordering is primarily 1D and weak correlation between chains was established previously for a related surface structure [3]. The identification of the system with an antiferromagnetic Ising model depends on the defects that disrupt the order in the chain being more discrete than continuous in nature. This also is a quantitative issue. Another model study [4], stimulated by adsorption on nanotube bundles, shows that (short-range) order persists in finite chains of 10^3 units and fragmentation arises from internal thermal excitations which pre-empt the disruption of order by simple entropic bond breaking.

Rather general arguments, which can be made quite tight [5], establish the absence of phase transitions in one-dimensional models unless the interactions are very long range. As close attention is given to the structures that are realized on surfaces, the physical situation is found to be richer than might have been anticipated. One class of systems is adsorbates on nanotube bundles, studied mostly by thermodynamic techniques [6]. Another class is the nearly one-dimensional chain structures created on vicinal surfaces or reconstructed surfaces. The correlations in one such chain were shown to depend on long-range interactions mediated by the supporting substrate [3]. The chains at surfaces are more accessible to experiments

E-mail address: lwbruch@wisc.edu

0039-6028/$ - see front matter
doi:10.1016/j.susc.2005.04.055

than the nearly one-dimensional structures embedded in three-dimensional solids [7], where "external potentials" stabilize one-dimensional lattices. Thus, the paper of Erwin and Hellberg may stimulate another round of creative interactions of theory and experiment as occurred, for instance, in monolayer adsorption [8].

Acknowledgement

This work has been partially supported by NSF-DMR0104300.

References

[1] S.C. Erwin, C.S. Hellberg, Surf. Sci. 585 (3) (2005) L171.
[2] E.g., K.M. Rabe, J.D. Joannopoulos, A.N. Berker18th International Conference on the Physics of Semiconductors, vol. 2, World Scientific, Singapore, 1987, p. 1221;
H.J. Choi, D. Roundy, H. Sun, M.L. Cohen, S.G. Louie, Phys. Rev. B 66 (2002) 020513.
[3] A. Kirakosian, R. Bennewitz, F.J. Himpsel, L.W. Bruch, Phys. Rev. B 67 (2003) 205412;
J.L. McChesney, J.N. Crain, V. Pérez-Dieste, F. Zheng, M.C. Gallagher, M. Bissen, C. Gundelach, F.J. Himpsel, Phys. Rev. B 70 (2004) 195430.
[4] J.M. Phillips J.G. Dash, J. Stat. Phys. (in press).
[5] R.E. Peierls, Ann. Inst. Henri Poincaré 5 (1935) 177;
N.D. Mermin, H. Wagner, Phys. Rev. Lett. 17 (1966) 1133.
[6] M.M. Calbi, M.W. Cole, S.M. Gatica, M.J. Bojan, G. Stan, Rev. Mod. Phys. 73 (2001) 857.
[7] H.J. Mikeska, M. Steiner, Adv. Phys. 40 (1991) 191.
[8] L.W. Bruch, M.W. Cole, E. Zaremba, Physical Adsorption: Forces and Phenomena, Oxford University Press, Oxford, 1997.